Defining String Theory

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APS/DPF meeting
Philadelphia, PA
April 5, 2003
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What is string theory?

Until recently,

set of rules for perturbation theory

Computes on-shell scattering of gauge quanta, gravitons

Perturbative expansion of quantum theory of gravity

- No nonperturbative formulation
- Space-time background fixed
Nonperturbative formulations

Two nonperturbative descriptions of string/M-theory have emerged in last 5 years.

M(atrix) theory:

\[ \text{M-theory in flat space-time} = \text{supersymmetric matrix quantum mechanics} \]

\[ S = \text{Tr} \ x_i^2 + [x_i, x_j]^2 \]

AdS/CFT:

\[ \text{IIIB string theory in AdS}_5 \times S^5 = \text{4D supersymmetric Yang-Mills theory} \]

In both cases, geometry emerges in a nontrivial way

M(atrix) theory: noncommutative matrix geometry

AdS/CFT: holography (scale/radius duality)
In M(atrix) theory and AdS/CFT, asymptotic form of the space-time background is fixed.

Can address local problems (e.g. black holes).
Cannot address global problems (cosmology).

To change asymptotic background:
must add $\infty$ number of nonrenormalizable interactions.

- Example: noncommutative field theory

$$\phi \star \psi = e^{i\theta^{ij}\partial_i \partial'_j} \phi(x)\psi(x')$$

Gives sensible nonlocal field theories.

- Nonlocal field theories arise naturally from string theory.
- How can we systematically treat such nonlocal theories?
String field theory has aspects of background independence

[SFT = nonlocal field theory in target space, \( \infty \neq \text{fields} \)]

In recent years, motivated by Sen conjectures:

Simplest (open bosonic) SFT has multiple vacua

Solution known only numerically, no analytic control

But:

Theory contains two geometrically and topologically distinct open string vacua, not connected by continuous (marginal) deformations
Emergent geometry?

We need a similar story for closed strings

Framework is desired in which different space-time geometries/topologies arise from a single underlying theory

- Theory may have non-geometric definition
- Appropriate mathematics may not yet exist
- Difficult problem, but critical for string cosmology

Some approaches which go beyond classical geometry:

- Noncommutative geometry/noncommutative algebra
- Derived category program/K-theory
- String field theory

None of these approaches yet gives a complete background-independent dynamical theory.
Geometry from closed strings in SFT?

A promising approach: Attempt to replicate success of open string field theory for closed strings (geometry)

Closed string field theory?

- Existing formalism complicated, but possibly tractable

Closed strings in open string field theory?

- Closed strings appear in open string loops

$$\text{C} \quad \Rightarrow \quad \text{open string loops}$$

- Quantum open string field theory may contain closed strings
- M(atrix) theory, AdS/CFT as limits of closed/open SFT correspondence?
- Can we study closed string vacua (different space-time geometries) from this point of view?